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Spatio-Temporal Change of Dispersal Areas of Greater Kudu (*Tragelaphus strepsiceros*) in Lake Bogoria Landscape, Kenya

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Abstract

Decline in wildlife populations is manifest globally, regionally and locally. A wildlife decline of 68% has been reported in Kenya's rangelands with Baringo County experiencing more than 85% wildlife loss in the last four decades. Greater Kudu (*Tragelaphus strepsiceros*) is endemic to Lake Bogoria landscape in Baringo County and constitutes a major tourist attraction for the region necessitating use of its photo on the County's logo and thus a flagship species. Tourism plays a central role in Baringo County's economy and is a major source of potential growth and employment creation. The study was carried out to assess spatio-temporal change of dispersal areas of Greater Kudu (GK) in Lake Bogoria landscape in the last four years for enhanced adaptive management and improved livelihoods. GK population distribution primary data collected in December 2022 and secondary data acquired from Lake Bogoria National Game Reserve (LBNGR) for 2019 and 2020 were digitized using in a Geographic Information System (GIS). Measures of dispersion and point pattern analysis (PPA) were used to analyze dispersal of GK population using GIS. Spatio-temporal change of GK dispersal in LBNR was evident thus the null hypothesis was rejected. It is recommended that anthropogenic activities contributing to GK's habitat degradation be curbed by providing alternative livelihood sources and promoting community adoption of sustainable technologies for improved livelihoods.

Keywords

Spatio-Temporal Change, Dispersal, Greater Kudu (*Tragelaphus Strepsiceros*), Point Pattern Analysis (PPA), GIS

1. Introduction

Globally, an average of 69% decline in the relative abundance of monitored wildlife populations around the world between 1970 and 2018 has been reported [1]. Further, wildlife population's decline of 68% between 1977 and 2016 has been reported in Kenya's rangelands [2]. These declines have been attributed to rapid growth in human population and associated pressures on resources, institutional and market failures, impacts of climate change and variability, lack of development in the rangelands and ineffective wildlife conservation policies, strategies and practices in Kenya [2] [3]. World Bank report of 2019 listed Baringo County among the few counties in Kenya that experienced over 85% wildlife loss in the last four decades [4].

The Greater Kudu (*Tragelaphus strepsiceros*) range extends from Ethiopia, Eritrea, Kenya, Tanzania, and the southern part of the continent, particularly in Angola, Zambia, Botswana, Namibia, Zimbabwe and South Africa [1]. Greater Kudu with its magnificent spiraled horns is one of Africa's most gracious and handsome antelope [5]. Besides being a major tourist attraction for Baringo County necessitating use of its photo on the County's logo (a flagship species), its direct and indirect contribution to food and environmental security cannot be overemphasized. It is indicated that 92% of all the County's tourists visited Lake Bogoria National Game Reserve (LBNGR) in the year 2017 [6] and thus a huge revenue base. However, as one of the most important tourist attractions in Baringo County, there is a growing concern over the future of the Greater Kudu owing to the immense pressure on its habitat that is not only limited to the LBNGR but also the adjacent farmlands and community grazing lands [7].

The Greater Kudu dispersal areas are within the landscape that hosts LBNGR, a World Heritage Site, a Ramsar Site and an Important Bird Area [6]. Lake Bogoria National Game Reserve is known locally, nationally and regionally, for important wildlife species, including the flamingo and the Greater Kudu [7]. The Reserve has unique physiographic features and geothermal manifestations due to its geological history that portend well for tourism. The combination of landforms, biodiversity content, availability of water and forage makes it a preferred Kudu habitat and an important site at community, national and global levels [6].

Whereas Greater Kudu in IUCN Red List of 2020 is under the category of Least Concern species, it is endangered in Uganda and Somalia and is thought to be vulnerable in Chad and Kenya [8]. The status of the northern population is precarious due to overexploitation and habitat loss [9]. In fact, Greater Kudu is extinct in Djibouti and its presence is uncertain in Somalia, South Sudan, Sudan and Uganda [8]. It is also indicated that there is a continuing decline of Greater Kudu—more than 71% of mature populations of estimated at between 300,000 - 350,000 [8]. Lake Bogoria National Reserve's Integrated Management Plan (IMP) in the year 2007 listed Greater Kudu as threatened [10].

The growth in human population in the Bogoria landscape coupled with increased number of livestock and heightened agricultural expansion explains the landscape transformation and to some extent, the observed land degradation in the region [6] [9]. Human-induced changes in an ecosystem influence spatio-temporal dispersal changes of herbivore wildlife species by affecting forage abundance and nutritional quality, exposure to predators [11], modification of habitats and breeding areas [12]. Sinclair *et al.* (2007) found that abiotic events, such as droughts and floods, created disturbances that affected survivorship of ungulates of the Serengeti-Mara Ecosystem [13]. Similarly, spatial and temporal heterogeneity in the quality and quantity of food in savanna landscapes affected the distribution of native large herbivore [14]. Understanding spatio-temporal dispersal changes in a landscape will help in evaluating species interaction within their ecosystems and how these interactions are affected by climate and anthropogenic activities [13] [15]. This promotes coexistence of people and wildlife around protected areas, and by extension enhances wildlife conservation, food and environmental security.

It has been demonstrated that in a world with limited dispersal opportunities, the range size occupied by species is crucial for their survival and is responsible for their extinction than any other factor [16]. However, there is limited information and data on spatio-temporal dispersal changes of Greater Kudu range in LBNGR landscape to support management interventions. It is against this background that a study was carried out to assess spatio-temporal change of dispersal areas of Greater Kudu (*Tragelaphus strepsiceros*) in Lake Bogoria landscape in the last four years for enhanced adaptive management and improved livelihoods.

2. Materials and Methods

2.1. Study Area

Baringo is one of the 47 counties in Kenya. It is situated in the Rift Valley region. Baringo covers an area of 11,015.3 km^2 of which 165 km^2 is covered by surface water from Lake Baringo, Lake Bogoria, and Lake Kamnarok [6]. Lake Bogoria is the deepest alkaline lake in Kenya with numerous alkaline hot springs that contribute significant inflows into the lake. The Lake Bogoria National Reserve which is 107 km^2 comprises of the lake and the terrestrial portion with various vegetation types depending on soil types and terrain. Lake Bogoria National Game Reserve, lies between 36˚4' and 36˚7' East and 0˚20' North and about 10 km North of the equator in Baringo County (**Figure 1**). It has an altitude of between 970 m a.s.l at the lake to 1650 m a.s.l on Siracho escarpment. The Reserve lies close to the eastern wall of the Great Rift Valley and has its headquarters at Loboi Gate. Lake Bogoria drainage basin has three major soil types; clay soil, clay loam and silt loam. The climate in the plains is arid to semi-arid regimes except in the moist highlands around Subukia. Temperatures around the Lake range from 18˚C to 39˚C with a daily mean of 25˚C. Mean annual precipitation varies from 500 - 1000 mm and falls in two seasons April-May and October-November [6] [9]. According to the population and housing census conducted in 2019, the population of Baringo County was 666,763 showing positive trend [17]. There are six broad vegetation types in the Reserve: riverine forests, wooded bush land, bushed thicket, bush land, bushed grassland and swamps [10].

The area is rich in wildlife species characterized by a high diversity at low

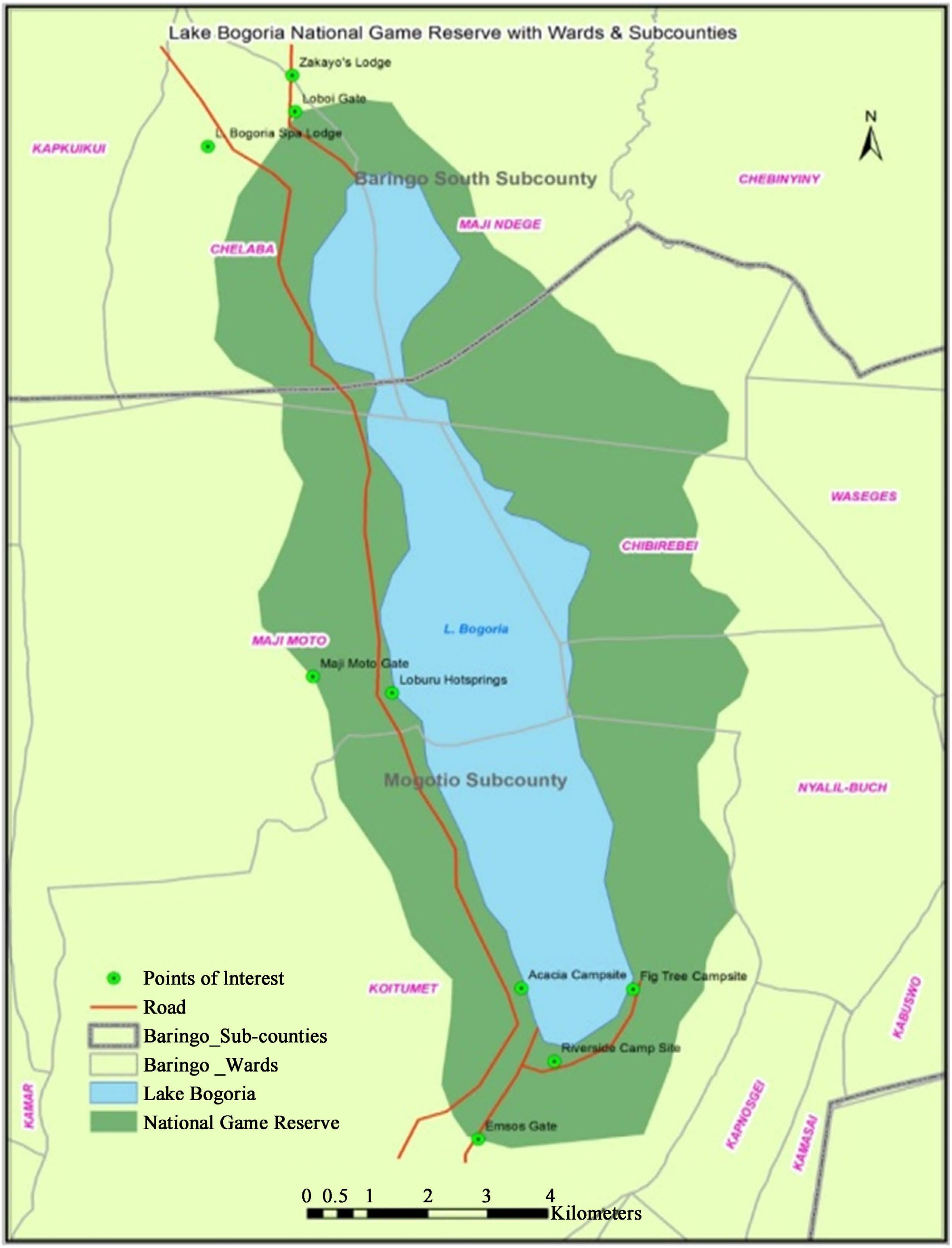

Figure 1. The Lake Bogoria National Reserve (Constructed by author using ArcGIS 10.8).

densities. Animals found in the plains of LBNGR include the Greater Kudu, impala, vervet monkey, dikdik, warthog, and common jackal, among others. There are several reptiles that include monitor lizard, lizards, tortoise, crocodiles and various species of snakes, and over 373 species of birds [6].

2.2. Research Design and Data Collection

Field studies to assess spatio-temporal change of dispersal of biodiversity are expensive, time consuming and need to be carried out over many years. However, they have some limitations because of the complexity of interactions and difficulty of generalizing the results. For this study, secondary data for two years was used to supplement primary data collected during the study period. Spatial distribution and dispersal areas of the Kudu were assessed using primary and secondary data of Kudu population count in a Geographic Information System (GIS).

The transect lines had been established in the year 2019 by Friends of Nature Bogoria (a regional wildlife conservation organization) with the aim to have Greater Kudu population counts across the year over different seasons although regular monitoring has been hampered by limited resources—hence census is carried out once every year during the dry season. Secondary data that had been collected by LBNGR since the year 2019 and data collected during the study period (2022) were used to assess the abundance, distribution and trends of Kudu population for the last four (4) years.

The distances of the identified Greater Kudus from the already laid out transect lines were recorded and their geographic positions captured using GPS. During the study period, data was collected during the dry season (December to March) a similar period when the secondary data was collected. For temporal analysis, secondary data from LBNR for years 2019 and 2020 for similar seasons (dry) were compared with the primary data. The data for the year 2021 was missing due to travel and activity restrictions associated with Covid-19 pandemic.

2.3. Data Analysis

The data collected of Greater Kudu population counts in the year 2022 was used to calculate the average density (number/km^2) in a GIS. This data was supplemented by Greater Kudu population secondary data acquired from LBNGR for year 2019 and 2020. The presence of Greater Kudus in a location was digitized as points using GIS software. The measures of dispersion and densities were then applied to the Greater Kudu population to show spatial spread within their range. Further, GIS density-based point pattern analysis (PPA) was used to characterize Greater Kudu distribution in the study area.

3. Results and Discussion

3.1. Greater Kudu Population Count

Based on transect line counts, the population of Greater Kudu (numbers) from 2019 to 2022 in the Lake Bogoria landscape is presented in **Figure 2**.

The population increase of Greater Kudu in the year 2022 is attributed to improved conservation campaigns and support by the conservation partners. This

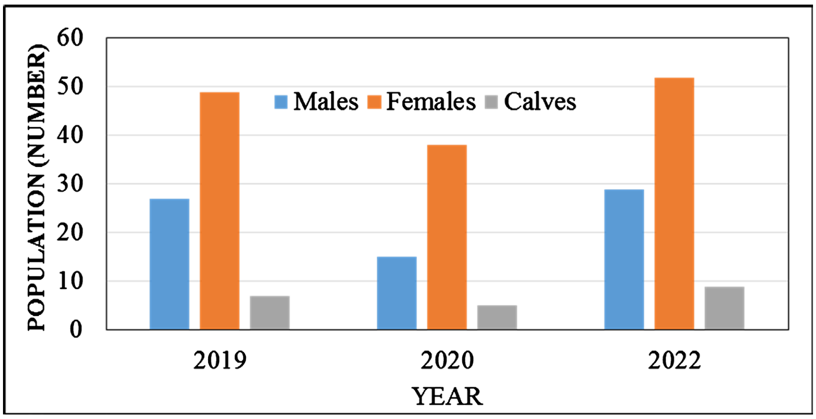

Figure 2. Greater Kudu population over the period 2019 to 2022 at LBNGR, Kenya.

has empowered the community to protect Kudus even when they stray to their farms because they know the benefit of its conservation. On the other hand, there was a decrease in Greater Kudus numbers in 2020. This decline was ascribed to above normal rainfall received in the study area. This may have affected breeding cycle of the Kudus which usually begins at the end of a rainy season or survival rate of the juveniles affected, and/or triggered herbivore migration [18]. Both *et al.* (2006), indicated that rainfall distribution determines onset of seasons which in turn affect biodiversity at the species level on timing of events like migration, dispersal and breeding habits populations [19]. Other studies have also shown that where there are plenty of food resources with minimum fluctuations between the years as is the case in the study area, the increase in rainfall may suppress Greater Kudu population growth [18].

3.2. Greater Kudu Population Density

The spatial distributions of sighted Kudus for the 3 years are presented in maps showing age and sex structured Greater Kudu population for the three years. According to [20], for the first two weeks after birth, Kudu calf hides where predators cannot find them. It was evident from this study that most of the calves stayed away from the rest of the group since they were still young to move around with the mother (**Figure 3**, **Figure 4**). It was also noted that Kudus were generally concentrated around the Lake. This observation was consistent with the findings of Simpson (1972) that Kudus concentrated around water points during annual dry season [21]. Thus, the sustainability of the Lake Bogoria is vital for the survival of the Greater Kudu. It is also an indication that there could be limited watering points in the landscape.

Comparing the three years, most Kudus were counted in the dense vegetation located more than 5km away from the Lake in 2019 (**Figure 5**). These numbers appear to have decreased over the years such that by the year 2022 (**Figure 3**), most Kudus occupied areas not far from the Lake. This implies that their terrestrial habitat could be facing disturbances from socio-economic activities as was also observed by Aduma *et al.* (2018) that human activities like agriculture and

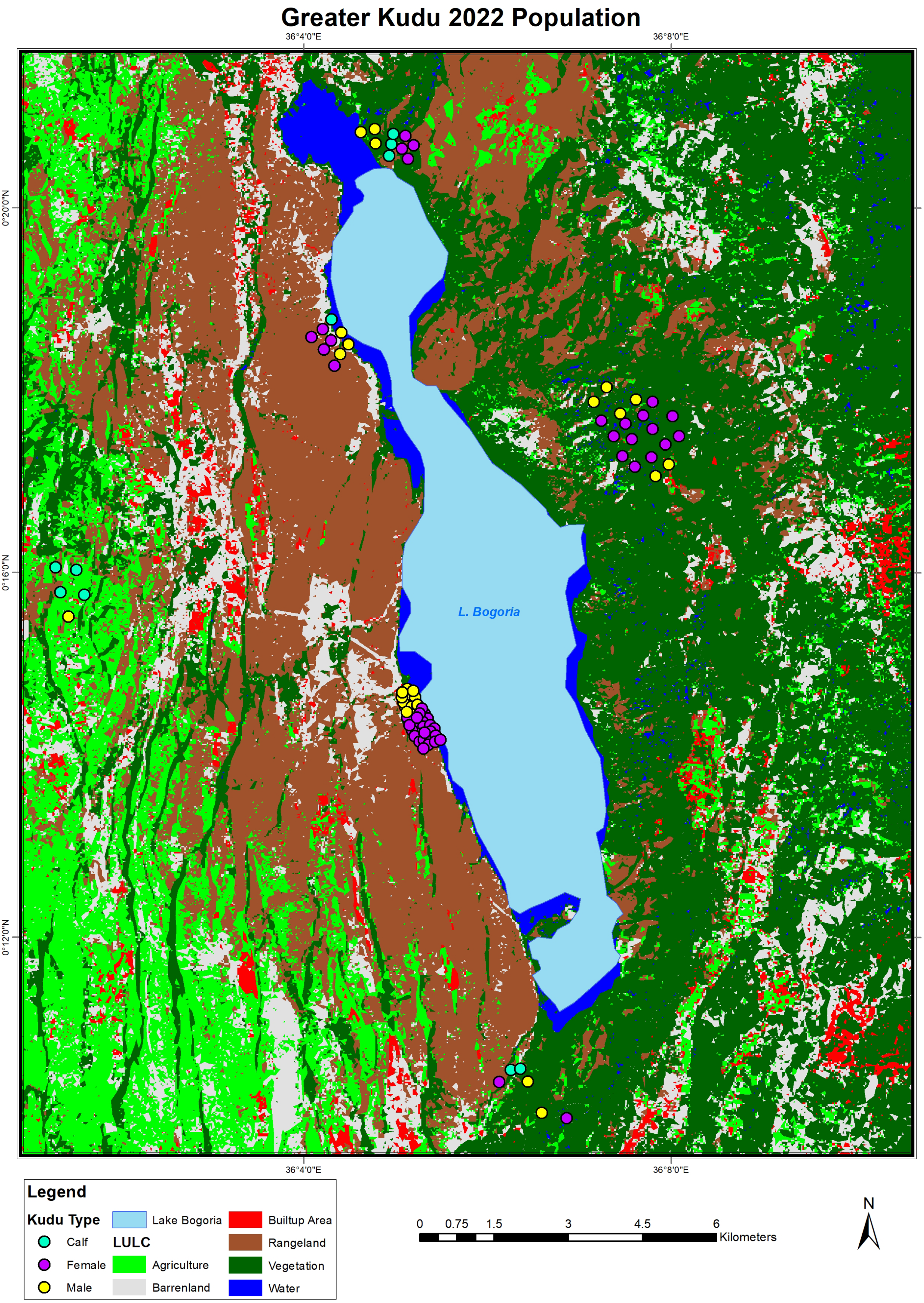

Figure 3. Greater Kudu population (2022) at the LBNR and its environs.

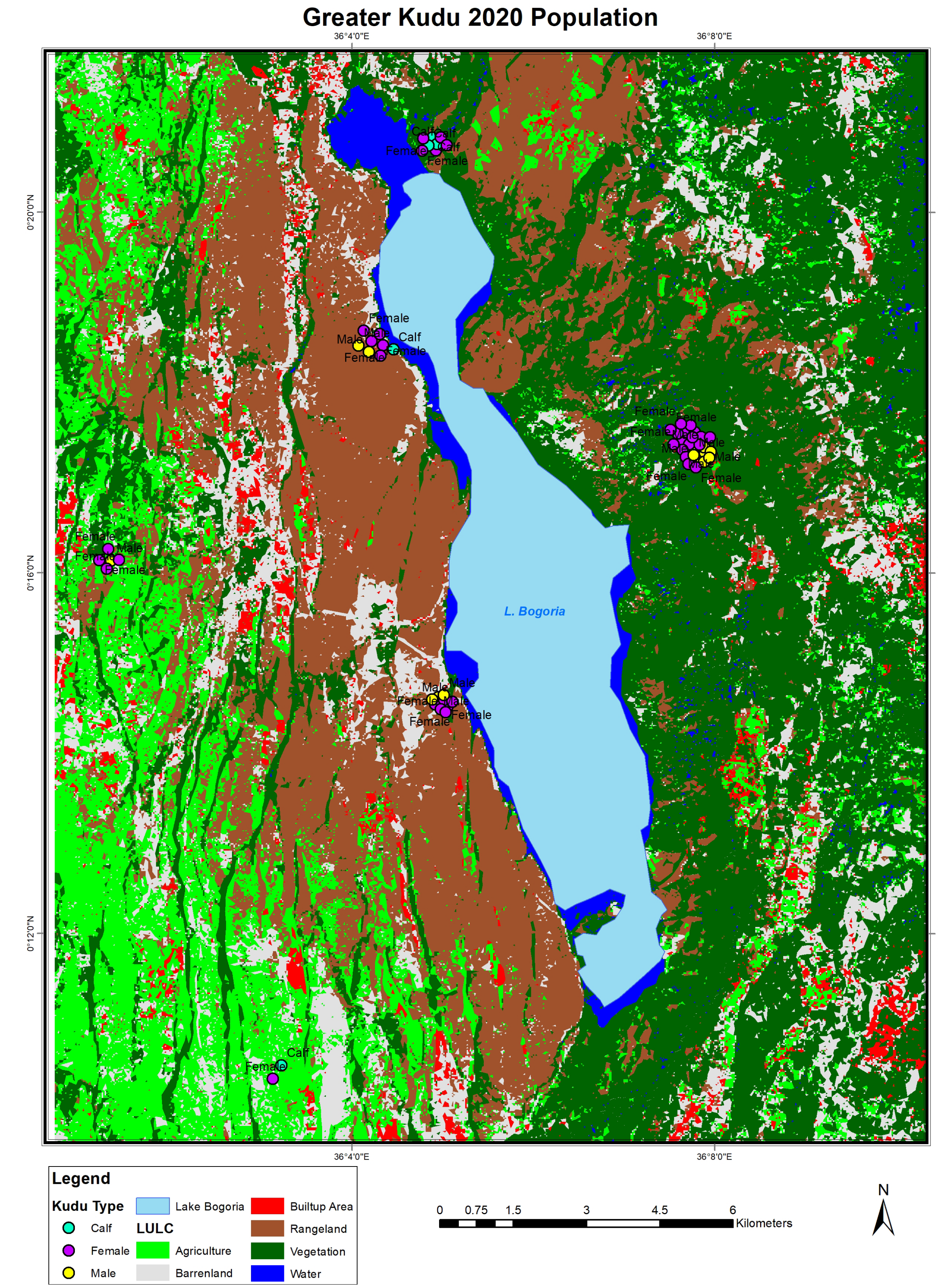

Figure 4. Greater Kudu population (2020) at the LBNR and its environs.

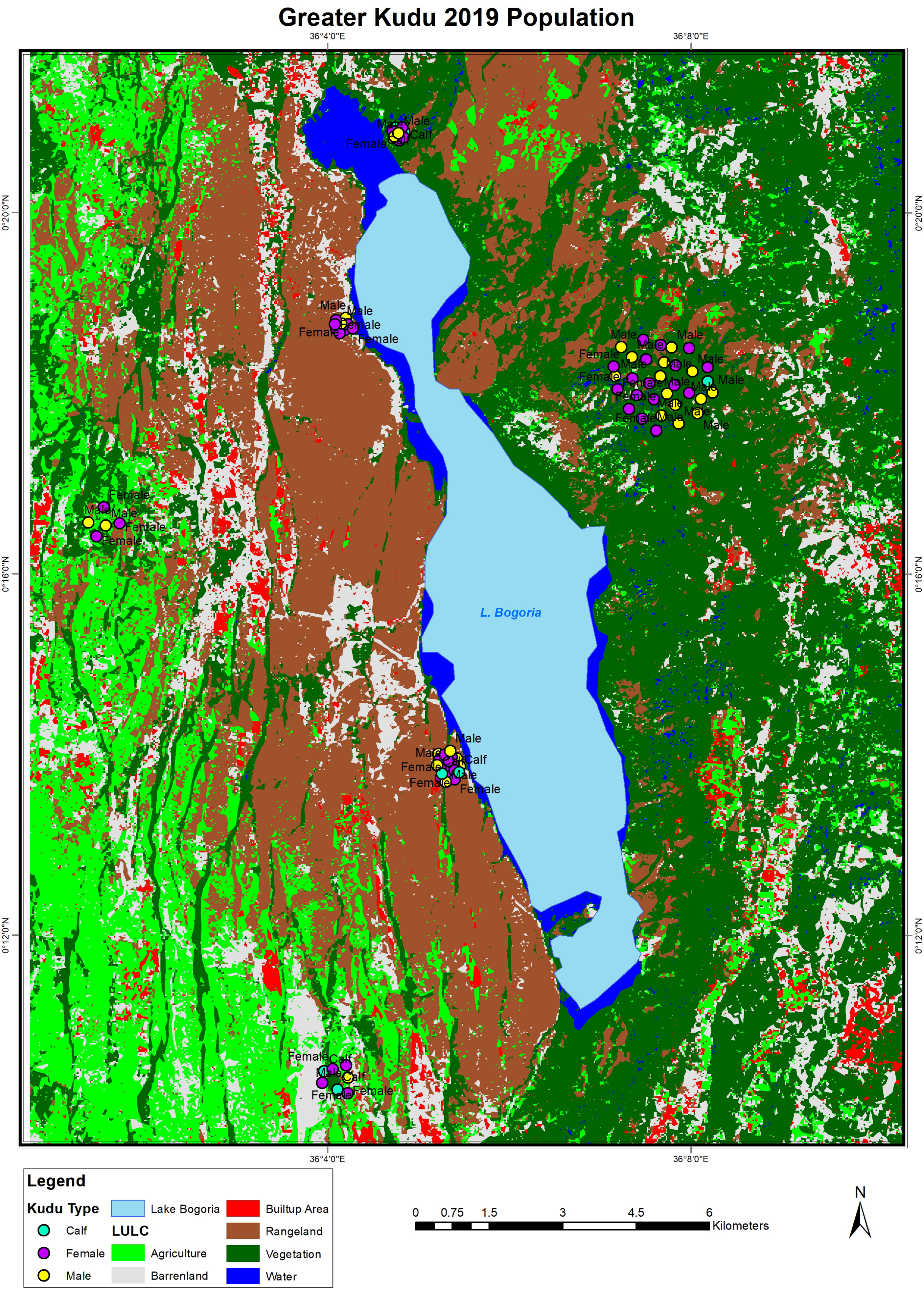

Figure 5. Greater Kudu population (2019) at the LBNR and its environs.

settlements interfere with migration or dispersal of wildlife [16].

3.3. Point Pattern Analysis

Point Pattern Analysis showed that for the year 2019, Greater Kudu dispersal map had a high density of between 10 and 40 Kudus/km^2 on the rangelands around Maji Moto and Koitumet wards (**Figure 6**). The depressed rainfall for all the seasons in 2019 contributed to this population pattern. Being shy, the Kudus numbers ranging between 1 and 10 Kudus/km^2 were sparsely spread on the western side of the Lake in the agricultural lands of Molos and Kamar wards. This may lead to Greater Kudu population instability and possibly local extinction due to increase in human-wildlife conflicts. Greater Kudu prefers to inhabit wood and thick bush land, mixed scrub woodland, mopane bush on lowlands, hills and mountains and anywhere with a constant supply of water [22] [23].

Greater Kudu dispersal map for the year 2020 (**Figure 7**) shows a high density of between 10 and 40 Kudus/km^2 in the leafy vegetation located in Maji Ndege and Chibirebei wards. This could be due to above normal rainfall for all the three seasons of the year (2020) in the landscape; most Kudus met their water needs elsewhere other than the Lake. The Kudus were densely populated in vegetated areas. Socio-economic activities tend to reduce the Greater Kudu population spread as was evidenced by low numbers ranging between 1 and 10/km^2 on the western side of the Lake in the agricultural lands of Koitumet and Kamar wards.

The dispersal map for year 2022 shows dense population of Greater Kudus (ranging between 40 and 50/km^2) near the shores of the Lake Bogoria in Koitumet sub-ward (**Figure 8**). More Kudus were also observed in Chibirebei and Maji Ndege wards in the highly vegetated areas around the Lake. Marginal numbers of Kudus ranging from 1 to 10/km^2 were seen in Tinosiek Olkokwe and Kamar wards, respectively which further affirms the importance of water sources/watering on dispersal of Greater Kudus [14] [21].

The ecosystem of the study area is characterized by agricultural lands (crop farming), wetlands, rangelands, grasslands, acacia forest/shrubland, water bodies, shrines, salt lick areas, conservancies, grazing areas, lodges and settlement areas. It is noteworthy that among factors that threaten Greater Kudu existence in the study area are poaching, human population creates pressure on land, scarcity of potable water hence limited watering points for Greater Kudus, habitat/corridors destruction due to agricultural activities, pests and diseases (Greater Kudus tend to be infested with ticks), extreme temperature and rainfall fluctuations, culture/indigenous knowledge erosion, encroachment to conservation areas and lack of ecosystem conservation awareness.

From the findings, it was evident that ecological needs of Greater Kudu affected their dispersal for instance; water requirements as was indicated by high concentration of Kudus around the Lake shores in the year 2019 when rains were depressed; food as the case for high concentration of Kudus in Chebirebei

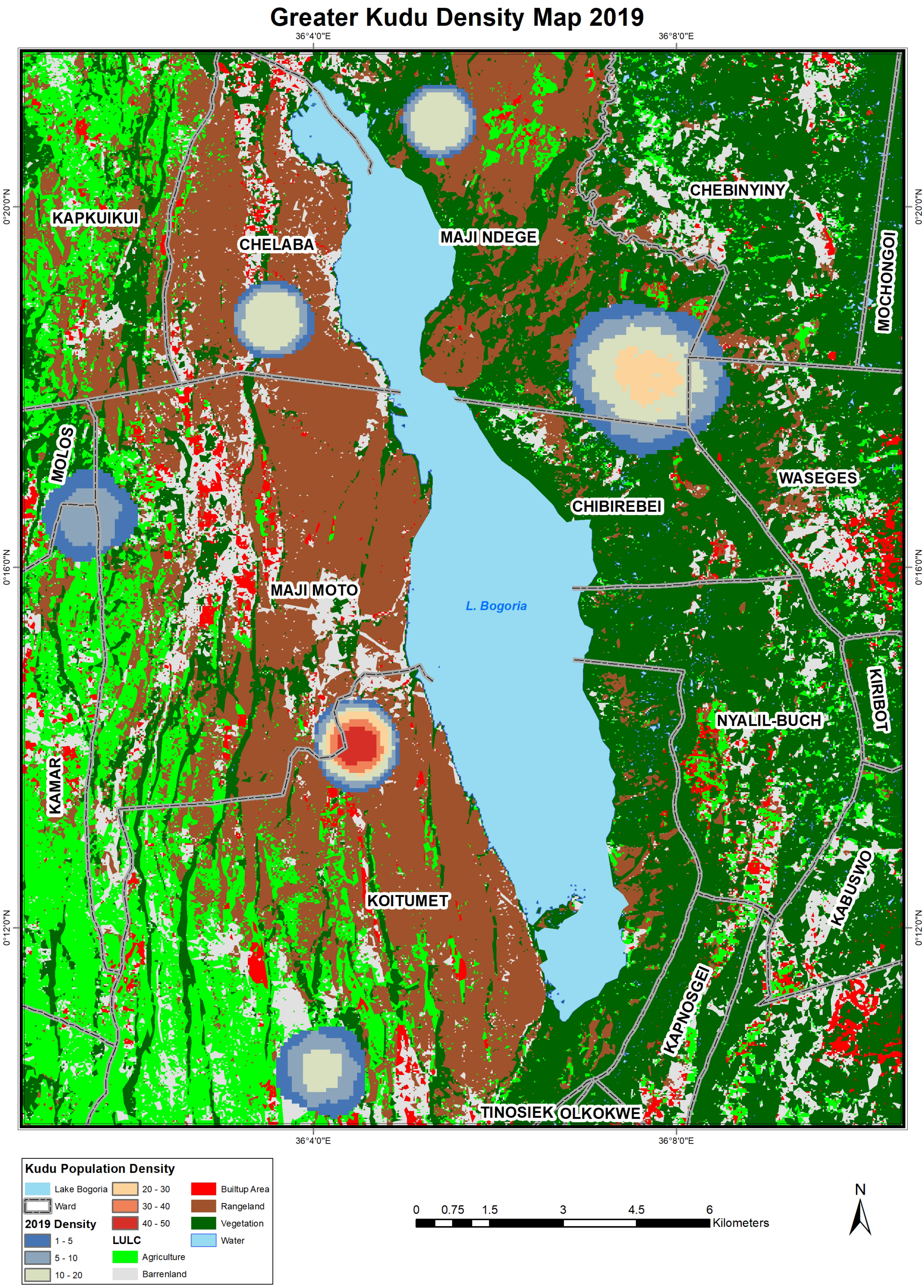

Figure 6. Greater Kudu population density (numbers/km2) for Year 2019 at LBNR.

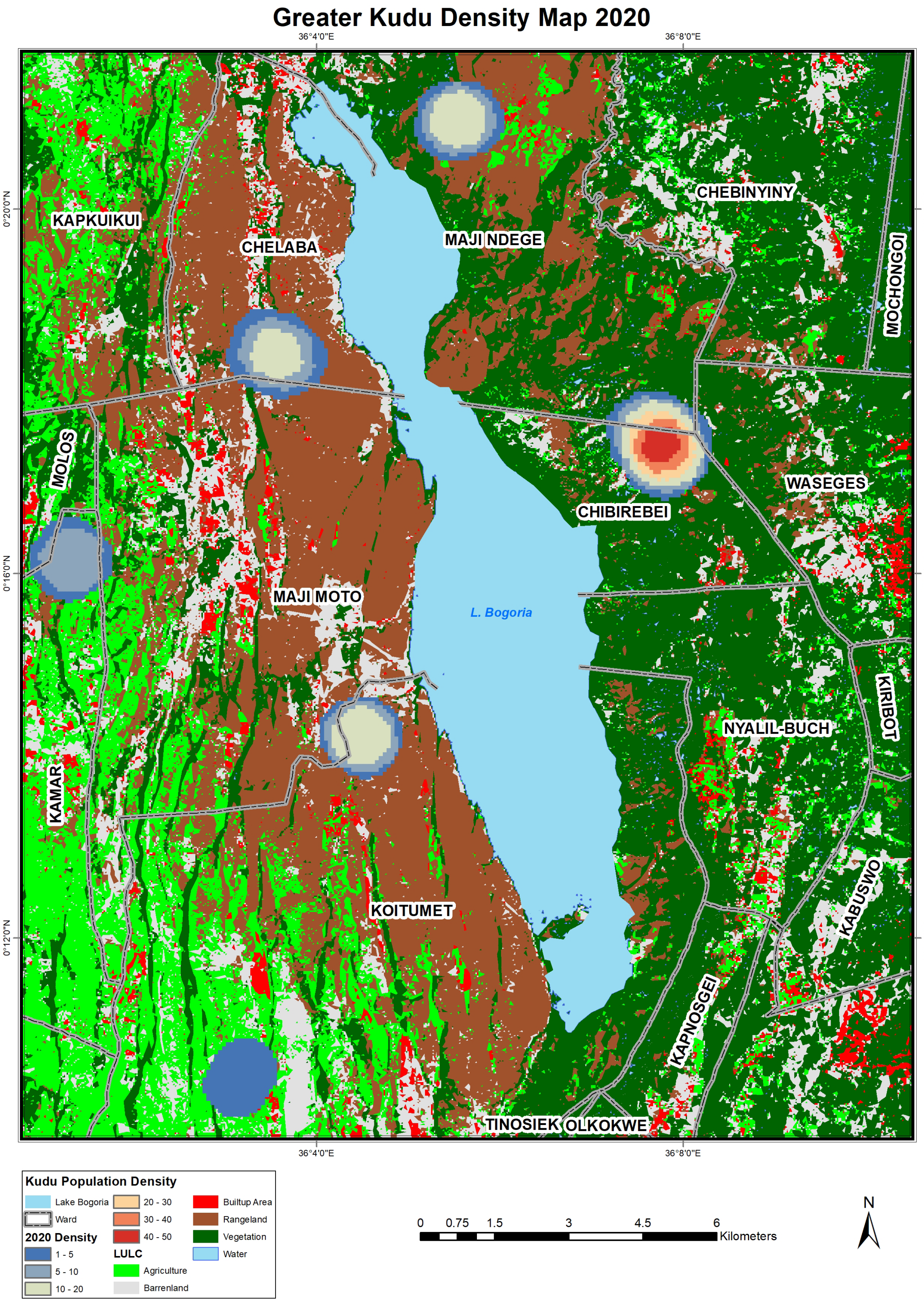

Figure 7. Greater Kudu population density (numbers/km2) for Year 2020 at LBNR.

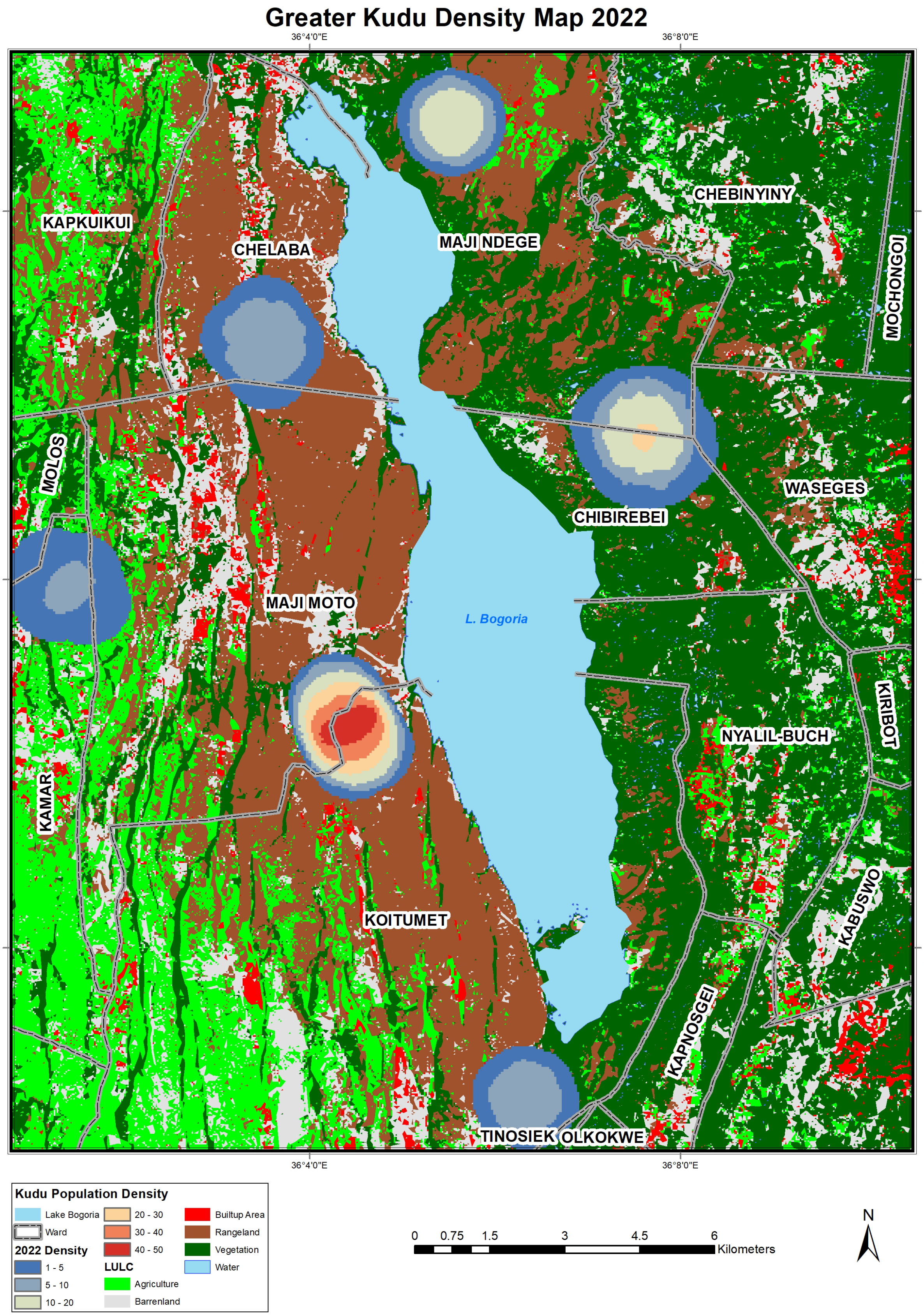

Figure 8. Greater Kudu population density (numbers/km2) for Year 2022 at LBNR.

ward in 2020; breeding behavior as is shown by dispersal of Kudu calves mostly being away from the mature herds; and their seasonal movement patterns or home range. This agrees with what Bennett (2003) indicated as factors to be considered when establishing and managing wildlife corridors [24].

For adaptive management of Greater Kudu and improved community livelihoods, sustainability is fundamental. Indigenous knowledge informing taboos and culture where only the most mature horn of Kudu is used in sacred rituals should be documented and preserved. Other activities like apiculture, smart agriculture (optimize land production to curb agricultural land expansion), establishment of monitoring transect lines and equitable revenue sharing for bursaries will promote Greater Kudu adaptive management and provide alternative revenue source for the community hence improved livelihoods.

Sustainable conservation of Greater Kudu calls for deliberate efforts by relevant stakeholders to increase in Greater Kudu watering points; identification, mapping and preservation of Greater Kudu corridors to minimize human-wildlife conflicts; pasture production to substitute natural forage for Greater Kudus; pest and disease management to be mainstreamed with Greater Kudu conservation to minimize their spread of ticks ad associated diseases to livestock; revenue sharing policy to be reviewed to ensure more resources generated from tourism is ploughed back for Greater Kudu conservation; regular Kudu census/monitoring; awareness creation through sensitizations and expansion of community conservancies; and beneficiaries of greater Kudu revenue bursaries to organize CSR activities towards adaptive management in the landscape.

4. Conclusion

From the findings, spatio-temporal changes of Greater Kudu population density were evident thus the null hypothesis that spatio-temporal distribution of dispersal areas of the Greater Kudu in Lake Bogoria landscape did not change in the last four years was rejected. It was recommended that factors contributing to changes in dispersal of Greater Kudu be assessed for enhanced conservation and by extension improved livelihoods in LBNR, Baringo County.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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